Firm-Level Data Analysis of the Effects of Net Investment Income on Underwriting Cycles: An Application of Simultaneous Equations

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Abstract: This study tests two major theories of insurer underwriting cycles and extends the hypotheses to explain insurers' reserving behaviors. By applying a simultaneous equations model to cross-sectional and time-series firm-level data, this study proposes that insurers' net investment income can be used to explain both hypotheses regarding processes for establishing premiums and reserves. Our results confirm that the industry cycle phenomenon is reflected in individual firm dynamics. We find that net investment income is inversely related to both premiums and loss reserves, as expected, and we identify how the *magnitudes* of these effects correspond to the phases of the underwriting cycle. The results indicate that the effects are greatest in the hard market of underwriting cycles. Moreover, the yearly differential responses of premiums and reserves to net investment income are coincident with the formation of cycles.
[Keywords: underwriting cycles, investment income, simultaneous equations]

INTRODUCTION

The cyclical pattern of profitability in the property-liability insurance industry has been discussed for decades and competitive hypotheses have been tested to explain these cycles. Cycles exist because insurers adjust premiums to reflect changing demands from insureds and to reflect

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the past and the future expectation of losses. The corresponding adjustments of supply and demand move the equilibrium premium over years, thereby forming the cyclical pattern of profitability, which is the underwriting cycle we observe.[1]

Most of the earlier studies of underwriting cycles focus on how the pricing process contributes to underwriting cycles. The importance of investment income in determining the adequacy of premiums is mentioned in those studies, but this argument lacks rigorous testing. This study examines how premiums and loss reserves simultaneously respond to previous net investment income. The employment of the cross-sectional and time-series firm-level data enables this study to use a single variable—net investment income—to examine the capacity constraint and fluctuations-in-interest-rate hypotheses simultaneously. The extant literature examines the capacity constraint hypothesis and fluctuations-in-interest-rates hypothesis by identifying the relationship between surplus and premiums, and between interest rates and premiums, respectively.

The rational expectations hypothesis states that premiums are determined by discounting the expectations of future losses by a risk-adjusted interest rate, which can be obtained by applying a financial pricing model such as the capital asset pricing model (CAPM).[2] As a result, an inverse relationship between the discounted rates and premiums is expected. Research by Doherty and Kang (1988) confirms the inverse relationship between interest rates and premiums and relates the underwriting cycles to the fluctuations in interest rates. In addition, Fairley (1979) identifies the relationship between investment income and the underwriting process and further suggests an inverse relationship between the underwriting margin and investment return. In other words, an inverse effect of investment income on premiums is expected, which is attributed to the fact that the insurers may adjust the underwriting margin as the basis of premiums according to the gain/loss of the investment to reach a target rate of return on equity.

The capacity constraint hypothesis indicates that a lower previous year's surplus results in a higher current premium, thereby causing higher current profitability. Berger (1988) develops a model considering the dynamics of the cycle derived from one lag of the feedback of profits to surplus by excluding any consideration of expenses and investment income. Berger concludes that an increase in the prior period's surplus will cause the supply function to shift so that the supply quantity increases and price decreases as the risk charge declines. He also notes that this conclusion still holds when the model includes investment income, where the supply price is inversely related to the rate of return on investable funds, which suggests an inverse relationship between premiums and investment income.

Following research by Fairley (1979) and Berger (1988), which provides a basis for considering the effects of investment income in explaining the fluctuations-in-interest-rates and capacity constraint hypotheses, this study provides a rigorous test of the role of net investment income. We evaluate underwriting cycles by applying a simultaneous equations model to cross-sectional and time-series firm-level data. By applying a cross-sectional simultaneous equations model, not only can the dynamic interactions between the premiums and reserves processes be captured, but also the hypotheses about cycles of the pricing and reserving processes can be tested simultaneously.

The existing hypotheses are applied to explain underwriting cycles only as they pertain to changes in premiums. This study explores the conclusion by D'Arcy (1988) that interest rates affect the adequacy of both premiums and loss reserves. Because insurance firms determine the adequacy of premiums and loss reserves simultaneously, this study extends the two hypotheses to consider the reserving process. For each factor included in the hypotheses for explaining premiums, this study develops a corresponding dual hypothesis for capturing the effects on reserves. In addition, we use individual insurers' net investment income, not interest rates, to test the hypotheses concerning the reserving process.

Using a panel set of individual insurer financial data, we evaluate underwriting cycles based on individual insurers' yearly responses of the premiums to exogenous factors. Year-by-year analysis enables us to investigate whether the yearly responses present a cyclical pattern, and contribute to the formation of underwriting cycles.

In addition, we pool the data across two time periods (pre-1992 and post-1992) and compare the results for these two periods. We separate the data at 1992, when the combined ratio exhibits a dramatic increase over the previous period. Moreover, we estimate the sensitivity of premium relationships using the entire cross-sectional, time-series dataset with the inclusion of cycle dummies representing the phases of underwriting cycle.[3]

Our findings suggest that when firm-level data are employed to analyze underwriting cycles, the single variable, prior net investment income, is sufficient to test both the capacity constraint and fluctuations-in-interest-rates hypotheses. We also find that yearly differential responses of premiums and reserves do somewhat contribute to the formation of the underwriting cycles. Our results are consistent with Fung et al. (1998), which relies on *time-series* and *industry by-line data* and applies a vector autocorrelation model (VAR) to test the same hypotheses. Our study extends their work by using firm-level *panel* data, and using the simultaneous equations model, we achieve the same goal of VAR to test these two hypotheses simultaneously.[4]

The remainder of this paper is organized in the following manner. The development of the hypotheses is explained in Section II, and Section III describes the data and methodology. Section IV presents the empirical results and Section V concludes.

HYPOTHESES

Insurers establish premiums to reflect the present value of expected losses and expenses. Thus, higher expected losses and expenses imply higher premiums (Myers and Cohn, 1987). In addition, a premium increase is possibly attributed to higher exposures for future losses and may be associated with a higher level of loss reserves, assuming that insurers take into account the interdependency between premiums and reserves in determining their relative adequacy. Since these relationships imply interdependency between premiums and loss reserves, a model considering their dynamic interactions is needed in order to estimate the direction and magnitudes of the relationships.

In this study we propose a set of hypotheses that relate to our investigation of the role of investment income in the pricing and reserving process.

Hypothesis (1): Premiums are inversely related to prior net investment income.

Dual Hypothesis (1): Loss reserves are inversely related to prior net investment income.

In testing the fluctuations-in-interest-rates hypothesis, researchers employed interest rates to proxy investment gains and further identify the effects of interest rates on premiums (Doherty and Kang, 1988;Fung et al., 1998). For the test of the capacity constraint hypothesis, surplus is the conventional variable used to address its impacts on premiums (Berger, 1988; Gron, 1994). We utilize a single variable—net investment income—to investigate both hypotheses in the pricing and reserving processes. Since we are using firm-level data, which includes both time-series and cross-sectional data, the use of interest rates is problematic, as it is identical for all firms in each time period. Using firms' own net investment income, we can more accurately capture the effects of interest rates as they are passed through firm's investment returns. Fung et al. (1998) note that "higher interest rates generate greater investment income, which lowers premiums and vice versa." They explicitly test the inverse relationship between the interest rates and the premiums and implicitly suggest the same relationship between the premiums and the investment income. An individual firm's net investment returns are, of course, affected by both systematic and idiosyncratic, company-specific risk. Thus, our analysis implicitly assumes insurers' premium and reserving processes are affected by both industry-wide shocks and firm-specific shocks, such as an asset duration mismatch. While we believe industry-wide shocks are more pertinent to the formation of the industry underwriting cycles, the cycle is manifest in actual performance, but the additional variation in investment returns across firms due to micro-level shocks is not likely to have as significant an effect on our results.[5]

The effects of investment income either on premiums or on reserves can be obtained when the entire system model reaches the equilibrium status, which suggests that the investigation of the effect of investment income on the underwriting cycles also considers the interdependence between premiums and reserves. The conventional regression model for testing the capacity constraint hypothesis is set up as follows, when industry-level time series data are used (Fung et al., 1998):

$$Premium_t = a'_1 + a'_2 Premium_{t-1} + a'_3 Losses_{t-1} + a'_4 Surplus_{t-1} + a'_5 OUE_t + \varepsilon_{1t} \qquad (1)$$

where OUE is "other underwriting expenses."

The use of surplus creates an interdependent correlation among the exogenous variables and an invalid relationship between surplus and premiums in equation (1). Therefore, a proxy for surplus is needed when using firm-level data to test the capacity constraint hypothesis and accurately distinguish the effects of each variable.[6] Net investment income is the most appropriate proxy for surplus, because net investment income contributes most to the amount of surplus. For these reasons, we suggest that an insurer's net investment income can be used to simultaneously test the capacity constraint hypothesis and the fluctuation-in-interest-rates hypothesis in the pricing and reserving processes. Furthermore, the direct effect of investment income on premiums and reserves can be identified.

DATA AND METHODOLOGY

The data we use are from the National Association of Insurance Commissioners (NAIC), and include annual statement data from U.S. property and liability insurers for the period 1985 through 1999. The total

Table 1. Descriptive Statistics for Sample Firms ($100 millions)

Variables	1986 Mean (std. dev.)	1993 Mean (std. dev.)	1999 Mean (std. dev.)
Net premiums written $_t$	1.396	1.816	2.238
	5.069	7.274	8.895
Net premiums written $_{t-1}$	1.107	1.716	2.197
	4.144	7.045	8.561
Loss incurred and loss adjustment expense incurred $_t$	1.035	1.395	1.697
	3.889	5.828	6.597
Loss incurred and loss adjustment expense incurred $_{t-1}$	0.890	1.542	1.607
	3.381	7.227	6.240
Net investment income $_t$	0.235	0.359	0.485
	0.779	1.130	1.648
Net investment income $_{t-1}$	0.208	0.385	0.555
	0.715	1.243	2.101

number of property-liability insurance companies reporting to the NAIC ranges from 2,182 to 2,637 during this period.

To mitigate heterogeneity problems among firms, this analysis includes only those firms that operated for the entire period. Firms passing this 15-year survivorship scrutiny are likely to present stable growth. Furthermore, because the underwriting cycle typically is about six years in duration (Venezian, 1985), these firms might be more attuned to the cycle and would execute pricing and reserving changes in a more stable manner than newer entrants to the industry.[7] Approximately half of the sample, or 1,223 firms, passed this survivorship criterion.

We include only stock firms in our study, noting their ease of access to capital markets and their ability to participate in a variety of investment opportunities.[8] The fact that some insurers have changed from mutual firms to stock firms results in different numbers of sample observations in each year. The number of stock firms ranges from 732 to 750 in the analysis period. Table 1 presents descriptive statistics for the firms included in this study. We note that the average values for all key variables increased across the sample period.

We use a simultaneous equations model (SEM) to take into account the interactions between the premiums and future losses.[9] In this model, premiums and losses are regarded as the endogenous variables because of their interdependency. The exogenous variables include prior net investment income ($NinvG_{t-1}$), prior premiums (NPW_{t-1}), prior losses ($LIAE_{t-1}$), and other underwriting expenses (OUE_t).

A simultaneous equations model is useful for investigating how the endogenous variables interact with one another and how those exogenous variables affect the endogenous variables after taking into account the dynamic interactions among endogenous variables, consequently achieving an equilibrium status in the dynamic system. Our model is constructed from two structural-equations, each of which presents the relationship among the endogenous variables and relationships between exogenous variables and endogenous variables. Hence, the structural-equations in this study can be written as:

$$NPW_t = a_0 + a_1 LIAE_t + a_2 NPW_{t-1} + a_3 NinvG_{t-1} + a_4 OUE_t + \varepsilon_{1t} \quad (2)$$

$$LIAE_t = \beta_0 + \beta_1 NPW_{t-1} + \beta_2 LIAE_{t-1} + \beta_3 NinvG_{t-1} + \varepsilon_{2t} \quad (3)$$

Structural-equation (2) suggests that the determination of current net premium written (NPW_t) depends on the previous year's net premium written (NPW_{t-1}), future underwriting expenses (OUE_t), and the previous year's net investment income ($NinvG_{t-1}$). And structural-equation (3) states that expected future losses ($LIAE_t$) are presumed to be affected by the prior losses ($LIAE_{t-1}$) and the previous year's net investment income ($NinvG_{t-1}$). Note that prior losses may affect current premiums and that prior premiums may affect the current losses as well. Since current losses, in structural-equation (2), can explain a large portion of prior losses, $LIAE_{(t-1)}$ is not included in structural-equation (3). For the same reason, prior premiums are not included in structural-equation (3). Nevertheless, the effects of $LIAE_{(t-1)}$ on NPW_t and of $NPW_{(t-1)}$ on $LIAE_t$ prevail through the reduced-form equations of the simultaneous equations model. The omission of $LIAE_{(t-1)}$ and $NPW_{(t-1)}$ in structural-equations (2) and (3), respectively, does not fade their effects on NPW_t and $LIAE_t$, respectively. Through the interaction function, as long as the exogenous variables are included in the dynamic system, their effects on the endogenous variables will prevail in the reduced-form equations of this system.

The structural-equations (2) and (3) indicate the temporary and indirect effects of the exogenous variables, NPW_{t-1}, $NinvG_{t-1}$, OUE_t, and $LIAE_{t-1}$, on the endogenous variables and the temporary equilibrium between endogenous variables, NPW_t and $LIAE_t$. To obtain the net effects of the exogenous variables on the endogenous variables, we estimate the reduced-form equations:

$$NPW_t = a'_0 + a'_2 NPW_{t-1} + a'_3 LIAE_{t-1} + a'_4 NinvG_{t-1} + a'_5 OUE_t + \varepsilon_{1t} \quad (4)$$

and

$$LIAE_t = \beta'_0 + \beta'_2 NPW_{t-1} + \beta'_3 LIAE_{t-1} + \beta'_4 NinvG_{t-1} + \beta'_5 OUE_t + \varepsilon_{2t} \quad (5)$$

Reduced-form equations (4) and (5) show the direct effects of the exogenous variables on the endogenous variables. That is, as long as the values of the exogenous variables are provided, the equilibrium values of the endogenous variables, NPW_t and $LIAE_t$, can be jointly determined.

In order to obtain statistically efficient and consistent estimates for the coefficients, we use a 3-stage least squared estimation (3SLS) methodology, which takes into account the information provided by the covariance matrix of error terms among and within the simultaneous equations, and estimates the parameters simultaneously from the structural equations.[10]

EMPIRICAL RESULTS

Our three sets of results from the reduced form of simultaneous equations model are presented in Tables 2–4. These include results from a yearly cross-sectional analysis, analysis of two subsamples (before and after 1992), and analysis of the pooled data for the entire time period, 1985–1999. Our interpretations of the results are based on the reduced-form equations of the dynamic system.[11]

Yearly Cross-Sectional Analysis

We begin by conducting a yearly analysis to deduce that the phenomena of underwriting cycles are driven by the yearly differential and cyclical responses of premiums to the exogenous variables. The coefficients of the exogenous variables in the reduced-form equations are measures of the total responses and sensitivities of the endogenous variables to a change in each exogenous variable after considering the interactions between the two endogenous variables. The differential responses of premiums to the exogenous variables provide the evidence of a cyclical premium pattern, and thus underwriting cycles are formed.

Panels A and B of Table 2 show the total and net effects of the exogenous variables on premiums and losses, respectively. The estimated negative coefficients on prior net investment income in both equations confirm that prior investment income inversely affects current premiums and reserves for most of the time periods. These results support hypothesis (1) and dual hypothesis (1) and assure the adequacy of applying prior net

Table 2. Results of Simultaneous Equations Estimation of Net Premium Written Model (4) and Loss Reserves Model (5): Year-by-Year Analysis

Year	Intercept	Net premiums written $_{t-1}$	Net investment income $_{t-1}$	Underwriting expenses $_t$	Losses and loss adjustment expenses $_{t-1}$
	Panel A: Estimated coefficients from net premium written model (4) (standard errors in parentheses)				
1986	0.032*	0.716***	–0.203**	1.178***	0.207**
	(0.019)	(0.133)	(0.076)	(0.101)	(0.139)
1987	–0.002	0.762***	–0.794***	0.512***	0.416***
	(0.015)	(0.049)	(0.048)	(0.075)	(0.045)
1988	–0.001	0.694***	–1.282***	0.626***	0.489***
	(0.011)	(0.023)	(0.039)	(0.039)	(0.023)
1989	–0.016	1.054***	–0.365***	0.025	0.039
	(0.016)	(0.149)	(0.055)	(0.084)	(0.149)
1990	–0.004***	0.691***	–0.321***	0.659***	0.287***
	(0.015)	(0.074)	(0.036)	(0.067)	(0.071)
1991	0.011	0.394***	–0.805***	2.543***	0.044
	(0.030)	(0.049)	(0.077)	(0.130)	(0.077)
1992	–0.002**	0.567***	–0.230**	0.710***	0.360***
	(0.024)	(0.024)	(0.041)	(0.090)	(0.029)
1993	0.029	1.013***	–0.225**	0.570***	–0.098***
	(0.031)	(0.201)	(0.061)	(0.111)	(0.233)
1994	0.025*	0.928***	–0.050	0.247***	0.060**
	(0.016)	(0.054)	(0.033)	(0.054)	(0.051)
1995	–0.027	1.040***	–0.485***	0.627***	–0.098**
	(0.030)	(0.172)	(0.120)	(0.102)	(0.223)
1996	0.018	0.875***	–0.212***	0.728***	–0.019
	(0.022)	(0.076)	(0.064)	(0.063)	(0.092)
1997	–0.013	0.885***	–0.014	0.817***	–0.098
	(0.055)	(0.708)	(0.073)	(0.123)	(0.975)
1998	0.001	0.997***	–0.108***	0.282***	–0.065
	(0.030)	(0.063)	(0.031)	(0.080)	(0.092)
1999	–0.058	1.158***	0.010***	0.797***	–0.483***
	(0.060)	(0.122)	(0.049)	(0.207)	(0.223)
Avg.(i)	–0.004	0.841	–0.359	0.735	0.081
Stdev.(i)	0.018	0.213	0.369	0.576	0.312
MAD(i)	0.016	0.175	0.282	0.333	0.250

***: statistically significant at 1% level (two-tailed)
** : statistically significant at 5% level (two-tailed)
* : statistically significant at 10% level (two-tailed)
(i) The averages, standard deviations, and mean absolute deviations are calculated using only the significant coefficients.

Table 2. (*Continued*)

Year	Intercept	Net premiums written $_{t-1}$	Net investment income $_{t-1}$	Losses and loss adjustment expenses $_{t-1}$	Under-writing expenses $_t$ (i)
		Panel B: Estimated coefficients from loss reserves model (5) (standard errors in parentheses)			
1986	0.004	0.257***	–0.067	0.681***	0.423
	(0.012)	(0.017)	(0.040)	(0.026)	
1987	–0.011	0.077***	–0.250***	1.019***	0.052
	(0.013)	(0.029)	(0.046)	(0.046)	
1988	–0.005	0.110***	–1.214***	1.122***	0.099
	(0.011)	(0.020)	(0.052)	(0.034)	
1989	–0.056***	0.692***	–0.302*	0.267***	0.016
	(0.012)	(0.025)	(0.035)	(0.034)	
1990	–0.034***	0.271***	–0.350***	0.721***	0.258
	(0.010)	(0.019)	(0.021)	(0.025)	
1991	–0.028***	0.197***	–0.464**	0.450***	1.272
	(0.013)	(0.012)	(0.029)	(0.015)	
1992	–0.140***	0.268***	–0.323**	0.862***	0.336
	(0.049)	(0.094)	(0.095)	(0.121)	
1993	–0.027***	0.614***	0.082***	0.105***	0.345
	(0.018)	(0.012)	(0.025)	(0.012)	
1994	–0.027**	0.455***	–0.601***	0.599***	0.121
	(0.020)	(0.027)	(0.035)	(0.037)	
1995	–0.002	0.582***	–0.284	0.198***	0.351
	(0.021)	(0.024)	(0.057)	(0.028)	
1996	–0.027***	0.470***	–0.496***	0.405***	0.390
	(0.014)	(0.016)	(0.032)	(0.021)	
1997	–0.015	0.444***	–0.015	0.233***	0.410
	(0.012)	(0.015)	(0.016)	(0.019)	
1998	0.035**	0.288***	–0.078***	0.610***	0.082
	(0.018)	(0.029)	(0.017)	(0.041)	
1999	–0.024	0.406***	0.156***	0.347***	0.280
	(0.022)	(0.016)	(0.016)	(0.022)	
Avg.(ii)	–0.017	0.367	–0.274	0.544	0.317
Stdev. (ii)	0.049	0.187	0.371	0.313	n/a
MAD (ii)	0.030	0.157	0.251	0.258	n/a

***: statistically significant at 1% level (two-tailed)
** : statistically significant at 5% level (two-tailed)
* : statistically significant at 10% level (two-tailed)
(i) OUE_t is not included in the LIAE structural equation, so the standard error of the estimate is not shown in the results.
(ii) The averages, standard deviations, and mean absolute deviations are calculated using only the significant coefficients.

investment income to test both the capacity constraint hypothesis and the fluctuation-in-interest-rates hypothesis. In addition, the results corroborate the connection between loss reserve discounting and interest rates, which was developed by D'Arcy (1988), and suggest that discounted loss reserves are negatively related to the discounted rate derived from CAPM.

The consistent positive relationship between past premiums and current losses for each of the time periods, shown in Panel B, provides support for the rational expectations hypothesis: current premiums can help predict future losses. This result not only supports the rational expectations hypothesis, but also confirms the validity of the approach implemented by Fung et al. (1998), who test the rational expectations hypothesis by examining directly whether lagged premiums predict current losses to avoid the potential variable specification problems experienced in Niehaus and Terry (1993).

We evaluate the hypotheses stated earlier on the basis of not only the signs of the coefficients, but also their magnitudes.[12] The magnitudes reported show varying yearly responses of premiums and reserves to the exogenous variables. For example, Panel A shows that the estimated relationship between prior net investment income and current premiums written varies from –1.282 in 1988 to +0.010 in 1999. The relationship between premiums and current underwriting expenses is the most variable, ranging from +0.025 in 1989 to +2.543 in 1991. The underwriting expense measure, which by design, reflects all the expenses related to underwriting policies, is the second most influential factor in the determination of premiums. Among all the net effects of the exogenous variables on premiums, on average, the lagged value of losses incurred ($LIAE_{t-1}$) has the smallest effects on premiums. As expected, the influence of past premiums on current premiums is the largest because of the strong correlation between the prior year's business and current business. In addition, the variations across years in the coefficients on the exogenous variables, measured by the standard deviations or mean absolute deviations, support the notion of a cyclical premium response.

Figures 1–2 present graphically the magnitude of the responses of premiums and reserves to changes in $LIAE_{t-1}$ and $NinvG_{t-1}$. They indeed show that firms adjust their pricing and reserving practices to the changes in the exogenous variables in a cyclical manner. Among the effects of the exogenous variables, the sensitivities of premiums and reserves to net investment income, shown in Figure 2, illustrate an interesting phenomenon: both premiums and reserves have the same cyclical movements in response to prior net investment income before 1992, but between 1993 and 1997 the cyclical movements of the responses of premiums and reserves are not consistent with each other. Nevertheless, prior net investment

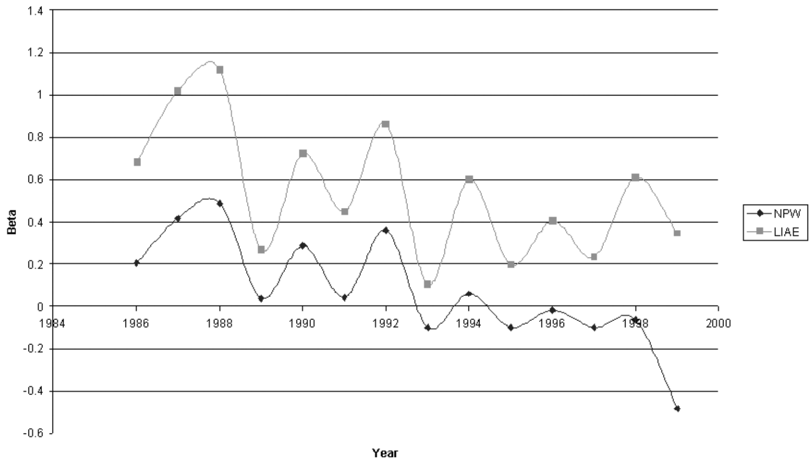

Fig. 1. Beta of $LIAR_{t-1}$.

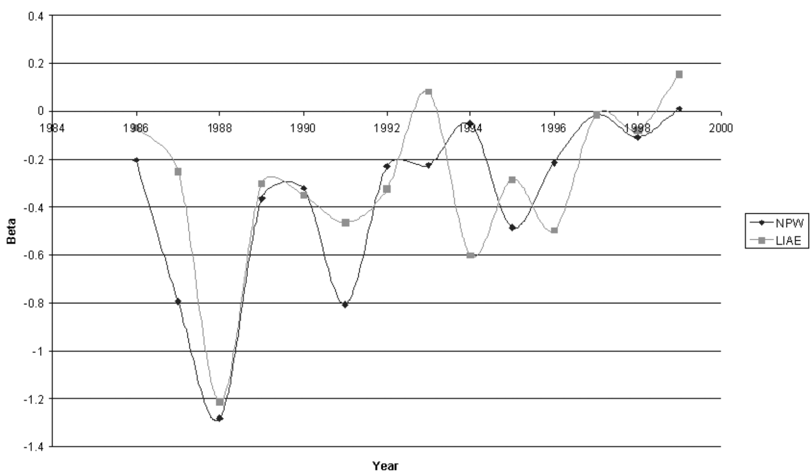

Fig. 2. Beta of $NinvG_{t-1}$.

income is inversely related to both premiums and reserves. One conjecture for the inconsistent responses in the period 1993–1999 is the occurrence of a major catastrophe in 1992—i.e., Hurricane Andrew. The results implicitly suggest that reserve adjustments depend not only on the level of investment income, but also on the occurrence of catastrophes. Sougiannis (1997) concludes that the market value response to catastrophe losses depends upon the stage of the underwriting cycle in which the catastrophe occurs. The author proposes that the occurrence of a catastrophe might cause temporary inconsistent results. This result also motivates a test of the hypotheses for the two distinct sub-periods.

Analysis of Two Sub-Samples (1985–1991 and 1993–1999)

The discrepancies among the estimated effects of the exogenous variables on premiums and reserves for the sample period, 1993–1997, suggest we consider a possible structural change in pricing behaviors when pooling cross-sectional data over time. Our next phase of analysis involves pooling our data into two time periods: before and after 1992. The differences in the estimated relationships between our key variables, as shown in Panel A of Table 2, motivate an analysis of the robustness of our results across the two separate time periods. For example, before 1992, the effects of $LIAE_{t-1}$ on current premiums (NPW_t) are positive, with coefficients ranging from +0.04 to +0.49. On the other hand, after 1992, $LIAE_{t-1}$ shows negative effects on NPW_t. While a test of a structural change is beyond the scope of our analysis, we split the data at 1992 to examine the consistency of the effects in these two separate periods. The results from the sub-sample 1993–1999 seem inconsistent with the hypothesis that past loss experience affects premiums positively. Fung et al. (1998) find that "the initial response of premium to an increase in losses is positive, but then negative after certain years for most of the lines." Our study suggests that even when firm-level data are employed, the negative effects of $LIAE_{t-1}$ on NPW_t after 1992 in reduced-form equations can still be explained by the "rational expectations with institutional lag" hypothesis.[13]

Consistently, both sub-samples substantiate the hypotheses of rational expectations, capacity constraints, and the fluctuation-in-interest-rates. The results of this analysis are presented in Table 3. Through the dynamic interactions between $LIAE_t$ and NPW_t, the "total" net effects of the exogenous variables on NPW_t and $LIAE_t$, respectively, for the period of 1985–1991, are shown. The inverse effects of prior net investment income on *NPW* and *LIAE* explicitly support the hypothesis that to determine the adequacy of premiums and reserves, firms would take into account the gains and losses on investments likely resulting from the volatility of interest rates. Hence, the fluctuation-in-interest-rates hypothesis is supported in the first sub-sample, 1985–1991. Moreover, the inverse effects of prior net investment income implicitly support the capacity constraint hypothesis, which emphasizes the inverse relationship between past surplus and premiums. Results of the first sub-sample show that the "total" net effect of past premiums on $LIAE_t$ supports the rational expectations

Table 3. Results of Simultaneous Equations Estimation of Net Premium Written Model (4) and Loss Reserves Model (5): Estimated Coefficients from Sub-Samples 1985–1991 and 1993–1999 (Standard Errors in Parentheses)

	1985–1991		1993–1999	
	Net premiums written (4)	Loss reserves (5)	Net premiums written (4)	Loss reserves (5)
Intercept	0.004	–0.021***	–0.008	–0.025*
	(0.010)	(0.005)	(0.009)	(0.012)
Net premiums written $_{t-1}$	0.673***	0.249***	0.892***	0.474***
	(0.028)	(0.007)	(0.021)	(0.010)
Losses and loss adjustment expenses $_{t-1}$	0.059***	0.632***	–0.006	0.340***
	(0.034)	(0.010)	(0.027)	(0.012)
Net investment income $_{t-1}$	–0.508***	–0.336***	–0.079***	–0.104***
	(0.028)	(0.015)	(0.012)	(0.015)
Underwriting expenses $_t^{(i)}$	1.495***	0.554	0.576***	0.306
	(0.042)		(0.025)	

***: statistically significant at 1% level (two-tailed)
** : statistically significant at 5% level (two-tailed)
* : statistically significant at 10% level (two-tailed)
(i) OUE_t is not included in the LIAE structural equation, so the standard error of the estimate is not shown in the results.

hypothesis, as the lagged premiums are used to predict current losses (Fung et al., 1998). In summary, the results from the first sub-sample are consistent with the hypotheses of the cycles, though the prior losses still appear to have only weak influence on current premiums.

The right-hand side of Table 3 reports the estimates of the same analysis for the period 1992–1999. The results for the $LIAE_t$ equation confirm that the lagged premiums can be used effectively to predict future losses, which is consistent with the rational expectations hypothesis. The estimates exhibit the inverse relationships between prior investment income and both premiums and reserves, which is consistent with hypothesis (1) and dual hypothesis (1).

Interestingly, past losses have a negative (but insignificant) effect on premiums in the second sub-sample. As discussed earlier, the negative relationship between past losses and current premiums may be attributed to the institutional lag. The discrepancy of the effects of past losses on current premiums in the two sub-samples, 1985–1991 and 1993–1999, suggests possible changes in pricing behaviors among insurance firms after 1992. It is essential for future study to identify the potential events, such as a catastrophe or new regulatory requirements, that intervene in the analysis of underwriting cycles and thus cause such different pricing behaviors around 1992.

Pooled Data Analysis 1985–1999

By adding annual cycle dummy variables to our equations, we can observe the magnitude of the responses of premiums and losses to net investment income in different phases of the underwriting cycles. Table 4 presents the results of the reduced-form equations with and without cycle dummy variables, for our entire data period, 1985 through 1999. Because our pooling analysis is based on the firm-level data instead of aggregating the values of each variable, our approach is different from the previous studies using industry-level data. In this study, we define soft markets in years 1989–1992 and 1999, which were characterized by decreasing profitability in terms of a high combined ratio; crisis markets in years 1985–1986, 1993–1994, and 1995–1996, when the industry exhibited increasing profitability in terms of decreasing combined ratios; and hard markets in years 1987–1988 and 1997–1998, characterized by high profitability in terms of low combined ratios.

The results consistently support the hypotheses that prior investment income inversely affects premiums and reserves. They also support the rational expectations hypothesis, as lagged premiums are used to predict the current losses. It is worthy to note that under this pooling analysis the past losses inversely affect current premiums in both cases, with and without dummy variables. Following the yearly analysis and sub-sample analysis, this study suggests that the existence of disturbance events causing possible structure changes may lead to a rejection of this hypothesis. Therefore, results obtained from an aggregated or pooled sample should be interpreted with caution.

The cycle dummies were added to examine the magnitudes of the effects from investment income on NPW_t and $LIAE_t$ in different phases of the cycle. The results from the reduced-form equations show that as the cycle is in the hard market phase, the negative impact of investment income on premiums and reserves is strongest, according to the estimated coefficients on $D_3{}^*NinvG_t$ in each equation. Tests of significance indicate that the effects of investment income on premiums are not significantly different when comparing the sort market and the hard market, but the effect of prior net investment income on premiums is significantly different (smaller) in the crisis market period, when compared to the other two periods.[14] A

Table 4. Results of Simultaneous Equations Estimation of Net Premium Written Model (4) and Loss Reserves Model (5): Estimated Coefficients for Sample Period: 1985–1999, with and without Cycle Dummies

$$NPW_t = a'_0 + D_1 + D_2 + a'_2 * NPW_{(t-1)} + a'_3 * LIAE_{(t-1)} + D_1 * a'_4 * NinvG_{(t-1)} + D_2 * a'_4 * NinvG_{(t-1)} + D_3 * a'_4 * NinvG_{(t-1)} + a'_5 * OUE_t + e_{1t}$$

$$LIAE_t = b'_0 + D_1 + D_2 + b'_2 * NPW_{(t-1)} + b'_3 * LIAE_{(t-1)} + D_1 * b'_4 * NinvG_{(t-1)} + D_2 * b'_4 * NinvG_{(t-1)} + D_3 * b'_4 * NinvG_{(t-1)} + b'_5 * OUE_t + e_{2t}$$

Note: D_1=1 if years 1989–1992 and 1999—soft market; D_2=1 if years 1985, 1986, 1993, 1994, 1995, and 1996—crisis market; D_3=1 if years 1987, 1988, 1997, and 1998—hard market.

	With Cycle dummies		Without Cycle dummies	
	Net premiums written (4)	Loss reserves (5)	Net premiums written (4)	Loss reserves (5)
Intercept	–0.009	–0.019	–0.0053	–0.024***
	(0.014)	(0.013)	(0.007)	(0.007)
D_1	–0.028*	–0.050**		
	(0.018)	(0.018)		
D_2	0.032*	0.006		
	(0.019)	(0.018)		
D_1* Net investment income $_{t-1}$	–0.161***	0.042***		
	(0.013)	(0.012)		
D_2* Net investment income $_{t-1}$	–0.086***	–0.225***		
	(0.016)	(0.015)		
D_3* Net investment income $_{t-1}$	–0.177***	–0.388***		
	(0.019)	(0.013)		
Net investment income $_{t-1}$			–0.1559***	–0.154***
			(0.011)	(0.011)
Net premiums written $_{t-1}$	0.860***	0.451***	0.8443***	0.435***
	(0.022)	(0.007)	(0.019)	(0.007)
Losses and loss adjustment expenses $_{t-1}$	–0.027***	0.357***	–0.0072	0.374***
	(0.028)	(0.009)	(0.024)	(0.009)
Underwriting expenses $_t$ (i)	0.820***	0.430	0.8280***	0.426
	(0.024)		(0.023)	

***: statistically significant at 1% level (two-tailed)
** : statistically significant at 5% level (two-tailed)
* : statistically significant at 10% level (two-tailed)
(i) OUE_t is not included in the LIAE structural equation, so the standard error of the estimate is not shown in the results.

similar test of the coefficients in the loss reserve equation reveals that the relationship between net investment income and losses is similar in the crisis and hard markets, but significantly different in the soft market period. Consistent with the implicit capacity constraint hypothesis (1), prior investment losses cause the decline in capacity and reduction in supply, so insurers raise premiums to compensate for the capacity shortfall. On the other hand, setting a fixed level of return on equity, insurers increase the underwriting margin in the wake of a reduction in investment income.

SUMMARY AND CONCLUSION

This study takes into account the interactions between loss reserves and premiums, and extends the analysis of hypotheses explaining the adjustment behaviors of both premiums and loss reserves. A simultaneous equations model is employed, and firm-level data are used to examine the responses of premiums and loss reserves to the changes in past premiums, past loss reserves, other underwriting expenses, and past net investment income. We show three sets of results that confirm the inverse relationship between net investment income and both premiums and reserves, and are consistent with the capacity constraint and fluctuation-in-interest-rates hypotheses. This study extends prior research by providing evidence that when firm-level data are employed, net investment income is a sufficient statistic to support the hypotheses regarding the insurance underwriting cycle.

The results of year-by-year analysis show that premium responses to the exogenous variables are cyclical, and thus partially explain the causes of underwriting cycles. Thus, we show that individual insurance companies adjust premiums and reserves in a cyclical manner to which the phenomenon of underwriting cycles is attributed. In addition, this analysis also suggests that some of the relationships may be stronger in some periods and may diverge from the hypothetical relationships in others, perhaps because of specific events amid the periods such as catastrophes or changes in regulatory requirements. Moreover, results of the yearly simultaneous equations model and sub-sample pooling data analysis show that premiums and loss reserves are negatively related to the previous year's net investment income, which supports both the hypotheses of capacity constraint and fluctuation-in-interest-rates.

Finally, while the results shown here are consistent with those in Fung et al. (1998), we provide evidence that when individual firm-level panel data are used, and firms' net investment income is used to proxy interest rates, and a different econometric methodology is applied, the hypotheses and the conclusions about the underwriting cycles are not jeopardized. Furthermore, this study provides an important basis from which to evaluate other individual firm characteristics and how they relate to insurance cycles. While we confirm that the industry cycle phenomenon is reflected in individual firm dynamics, future research should examine the variations in these cyclical responses across firms, especially with regard to varying levels of net investment income over time. An analysis of the differential effects on net investment income of macro-level shocks versus shocks internal to the firm may reveal new strategies for premium and loss reserving for firms weathering various stages of the insurance cycle.

NOTES

[1] The combined ratio is used to measure the underwriting cycles in this study. The combined ratio is defined as: $(LIAE_t)/PE_t + (OUE_t)/NPW_t$, where $LIAE_t$ is the sum of loss incurred and loss adjustment expenses of year t, PE_t is premium earned in year t, OUE_t is other underwriting expenses occurring at the time a policy is underwritten, and NPW_t is net premium written of year t. It is also defined as one minus the losses ratio minus the expenses ratio, where the sum of losses ratio and expenses ratio is called profitability. Therefore, a higher combined ratio indicates lower profitability.

[2] CAPM is used to determine an appropriate risk-adjusted rate after taking the undiversified risks into account. The basic format of the CAPM is $E(R_i) = R_f + ß_i (E(R_m) - R_f)$, where $E(R_i)$ is the expected return on asset i, R_f is risk-free rate of return, $E(R_m)$ is the return on the market portfolio, and $ß_i$ is ratio of the covariance of the return on asset i and the return on the market portfolio to the variance of the market portfolio return, which is a measure of the risk of asset i.

[3] Conventionally, the markets are recognized as hard and soft markets. The identification of the three phases of market—soft, crisis, and hard markets—are based on the definition of Sougiannis (1997).

[4] While our methodology, using a simultaneous equations model, is appropriate for extracting both time-series and cross-sectional effects, a panel VAR methodology also could be employed, but was beyond the scope of this study.

[5] AM Best (Best's Aggregate & Averages Property/Casualty 2001 Edition) indicates that roughly 55.4 percent of the property/casualty industry's assets are allocated in bonds, which is an investment tool highly correlated with the changes of interest rates. In addition, only 2.6 percent of the bonds were non-investment grade, which suggests that the investment quality may not be a major concern in analyzing an insurer's investment allocations.

[6] For any insurer, there exists an accounting identity equation among surplus, premiums, losses, net investment income, expenses, and other accounting variables—i.e., $Surplus_t = Premium^t + Net\ Investment\ Income_t - Losses_t + Other\ Accounting\ Numbers_t$.

[7] Employing this survivorship criterion allows us to mitigate the confounding effects of net investment income on underwriting cycles from those insolvent firms, but does introduce a potential bias because only successful firms remain in the sample.

[8] We expect that a similar analysis among mutual insurers would show that their performance and premiums are more sensitive to changes in their investment income.

[9] The use of cross-sectional SEM can achieve the same goal that Fung et al. (1998) achieve in applying vector autoregression (VAR) on time-series industry-level by-line data to test hypotheses of underwriting cycles simultaneously, and taking into account dynamic interactions between losses and premiums.

[10] As a result, the parameters estimates are derived on a general least squares basis, which takes into account the heteroskedasticity and autocorrelation problems.

[11] As Goldberger (1964) points out, "The reduced-form coefficient indicates the 'total' effect of a change in a specific exogenous variable (the conditional expectation of) on the endogenous variable after taking account of the interdependences among the current endogenous variables; in contrast, a structural coefficient indicates only a 'direct' effect within a single sector of the economy."

[12] Only the significant results from our yearly analysis are included in deriving the average net effect of each exogenous variable.

[13] This modified hypothesis suggests that premiums may not fully reflect the changes in losses immediately after the losses occurred because of the data collection lag, institutional lag, and regulatory lag (Cummins and Outreville, 1987). The length of such a lag and the factors associated with the adjustment are beyond the scope of the current study.

[14] The significance of differences in coefficients was calculated using a *t*-test and a 95% confidence level.

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